Optimal battery cells for grid-serving applications

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Abstract

Due to the current shutdown of baseload power plants and the further expansion of renewables, there is a change from generator-based power generation to inverter-based power generation in the electrical grid.This change has an impact on the services that ensure the stability of the electrical grid and are often provided by baseload power plants. In this context secondary batteries are expected to meet the requirements of grid-level large-scale electricalenergy storage such as peak shavingand load leveling, voltage and frequency regulation and emergency response. This paper presents an overview of current and future grid-serving applications and their characteristics. The characteristics are categorized so that they can be sorted by duration of provision, cycles per year, response time, etc. Furthermore, a market analysis of currently used storage systems regarding performance, dynamics, costs, life cycle assessment, resource availability, etc. is performed. Subsequently, a method for the coupling between the characteristics of a battery cell and the necessary requirements for grid-serving applications is presented. Depending on the application, properties are prioritized higher than others. The result of the developed approach provides a battery cell technology that fulfills the required properties as close as possible in order to ensure an optimal dimensioning and energy efficiency chain.

Keywords – *Battery cells, Cell characterization, grid services*

1 Introduction

In the context of the energy transition and the resulting expansion of renewable energies, the electrical grid is changing. With the expansion of inverter-based feed-in plants, generator-based nuclear and coal-fired power plants will be switched off and provide the services of the transmission system operators to stabilize the electrical grid. Already in 2020, the share of battery storage in the prequalified primary control reserve (PCR) has increased to 65% [1]. Furthermore, additional services and markets will open up in the future, e.g. for instantaneous reserve, black start capability or rotating masses, to provide these tasks. Various secondary battery systems are already used or investigated for grid storeage applications such as lead acid, lithium ion, nickel cadmium & - metal hydride, sodium sulphur and redox flow batteries. In this paper the aluminium dual ion battery (ADIB) will be investigated on its suitability for grid-serving applications. With its high cycle numbers and enormous power density it spans the gap between super capacitators and batteries offering key performance indicators.

2 Grid services

In this chapter, the grid-serving applications are shown. Table 1 contains a small part of the considered grid-serving applications, such as primary control reserve (PCR), reactive power supply (RPS), black start capability (BSC) and PV home storage (HS). In the summary of characteristics, the abstract shows the power required as well as energy for the application, energy to power ratio, duration, power gradient (dP/dt), response time, and estimated cycles per year.

TABLE 1 Grid services

Service	PCR	RPS	BSC	HS
P in kW	1000	no spec	130 – 50k	1 - 30
E in kWh	500	no spec	130 – 20k	3 - 45
E/P	0.5	no spec	1 - 4	1 - 3
Duration in s	900	arbitrary	10 - 14.4k	4k – 18k
dP/dt in kW/s	33.33	no spec	20	0.1
$t_{response}$ in s	30	240	0.001	0.001 - 1
Cycles per a	400	100	1 - 10	250 - 350

The fullpaper contains such as voltage level, obligatory, planable, responsible, etc.

3 Battery cells

Key performance indicators of batteries used for grid storage applications in comparioson to the ADIB

TABLE 2 Battery systems

Battery	Lead Acid	LIB	ADIB
E density in Wh/kg	40	90 - 250	40 - 55
P density in W/kg	180	250 - 340	500 - 5k
Efficiency in %	85	> 90 %	> 90 %
Lifespan in cycles	2500	1k -10k	20k – 100k

[1] Regelleistung-Online: In German: „Update 2020: Further growth of battery storage in the PRL market“. available https://www.regelleistung-online.de/update-2020-weiteres-wachstum-der-batteriespeicher-im-prl-markt/ [access at 28. October 2021]